

## METHOD OF ASSISTING THE DRIVER OF A VEHICLE

The invention relates to a method for assisting the driver of the vehicle in his steering activity, in which a steering torque can be applied to the steering wheel.

The invention also relates to a steering torque regulating module for a motor vehicle.

The invention also relates to a vehicle having a steering control system and a lane guidance system.

With "automatic" lane guidance, the driver of the vehicle is provided with a steering recommendation by an assistance system. In addition to the steering movements calculated by the assistance system, however, steering movements also occur due to feedback from interference due to the road and the vehicle driver himself. First, the system must compensate for such interference and, secondly, it must not compel the driver to drive in a certain direction against his wishes, because the driver of the vehicle may have to respond to an imminent threat or may want to execute a lane change.

The object of this invention is to create a method for assisting the driver of a vehicle in his steering activity such that it will ensure that the driver of the vehicle is assisted in a comfortable and secure manner in staying in his lane, but at the same time has control of the vehicle and retains responsibility for the steering activity.

This object is achieved by the features of the independent patent claims.

Preferred embodiments are characterized in the subclaims.

This object is achieved by a method for assisting the driver of a vehicle in his steering activity in which a steering torque can be applied to the steering wheel; this method is characterized in that an additional assistance torque  $M_{Ass}$  is applied to the steering wheel, assisting the driver of the vehicle in driving in a lane.

In the sense of this invention, this method provides maneuvering instructions for steering to the driver of the vehicle by providing an additional steering torque. The driver of the vehicle is assisted in staying in his lane by this haptic feedback in a manner that is comfortable for the driver.

If the driver of the vehicle complies with the handling instructions for steering, i.e., correctly implements the corresponding steering instructions through the additional steering torque, it remains certain that the driver is intentionally conforming to the steering process.

This yields as an advantage of the present invention the fact that the vehicle essentially cannot be steered against the intent of the driver of the vehicle. The driver of the vehicle also continues to feel responsible for the steering and therefore, will steer the vehicle according to his wishes.

According to this invention, it is provided that a current lane in which the vehicle is moving is determined and a steering recommendation is given to the driver of the vehicle by means of the additional assistance torque  $M_{Ass}$  applied to the steering

wheel so that the driver of the vehicle remains in the current lane.

Thus the driver of the vehicle is guided by the additional steering torque applied to the steering wheel, i.e., the assistant torque  $M_{ASS}$ , in steering to remain in one lane. The driver of the vehicle is receiving indications continuously through a continuous change in the additional assistance torque  $M_{ASS}$  applied while driving in a lane to show beyond which point, i.e., beyond which certain steering wheel setting the driver should not turn the steering wheel further in a certain direction. If the driver of the vehicle follows the handling instructions for steering, he will not perceive any increased resistance in his steering activity. He is thus able to securely and reliably keep his vehicle in the lane by himself. If the driver of the vehicle operates the steering wheel independently in such a manner that the steering operation proceeds optimally, i.e., if the driver steers "correctly" on his own, then there will be no change in the applied torque.

According to one embodiment, a manual torque  $M_H$  applied by the driver of the vehicle to the steering wheel or a quantity derived therefrom is determined, and the assistance torque  $M_{ASS}$  additionally applied to the steering wheel is variable as a function of the manual torque  $M_H$ .

According to this invention, the manual torque applied by the driver of the vehicle to the steering wheel or a quantity dependent thereon is determined over a lengthy period of time; a driver's steering intent is determined as a function of the curve of the manual torque plotted over time,; and the assistance torque  $M_{ASS}$  additionally applied to the steering wheel

is variable according to the driver's steering intent thus determined.

According to this invention, at least one maximum value for the assistance torque  $M_{ASS}$  (maximum assistance torque  $M_{max}$ ) applied additionally to the steering wheel is preselected; the manual torque  $M_H$  applied by the driver of the vehicle to the steering wheel is determined continuously; and the maximum assistance torque  $M_{max}$  is adapted dynamically to the manual torque  $M_H$  being applied at the moment by the driver of the vehicle to the steering wheel.

In one embodiment, at least one lower limit value (limit torque  $M_{H,LOW}$ ) for the additional assistance torque applied to the steering is preselected; the manual torque  $M_H$  applied by the driver of the vehicle to the steering wheel is determined continuously; and the manual torque  $M_H$  applied by the driver of the vehicle to the steering wheel is compensated by an additional compensation steering torque when the manual torque  $M_H$  thus determined does not exceed the lower limit value (limit torque  $M_{H,LOW}$ ). A value in the range of 0.7 Nm to 1.2 Nm is preferably preselected as the lower limit (limit torque  $M_{H,LOW}$ ) for the additional assistance torque applied to the steering wheel.

According to this invention, a signal of the manual torque  $M_H$  applied by the driver of the vehicle to the steering wheel is filtered, preferably by a low-pass filter of the first (1<sup>st</sup>) order. This filter advantageously has a filter-time constant of approximately 10 ms.

According to this invention, at least one lower limit value (limit torque  $M_{H,LOW}$ ) for the additional assistance torque applied to the steering wheel is preselected; the manual torque  $M_H$  applied by the driver of the vehicle to the steering wheel is determined continuously, and a lane-holding steering torque, which is required for guiding the vehicle in the given lane, is limited to a maximum value at least in an approximately linear ratio with an increase in manual torque  $M_H$  when the manual torque  $M_H$  thus determined exceeds the lower limit value (limit torque  $M_{H,LOW}$ ).

In one embodiment, at least one upper limit value (limit torque  $M_{H,HIGH}$ ) for the additional assistance torque applied to the steering wheel is preselected; the manual torque  $M_H$  applied by the driver of the vehicle to the steering wheel is determined continuously; and an intended steering torque which corresponds to a driver's intent after to a steering intervention measure is adjusted when the manual torque  $M_H$  thus determined exceeds the upper limit value (limit torque  $M_{H,HIGH}$ ). Preferably a value in the range of 1.8 Nm to 2.2 Nm is preselected as the upper limit value (limit torque  $M_{H,HIGH}$ ) for the additional assistance torque applied to the steering wheel.

According to this invention, the manual torque  $M_H$  applied by the driver of the vehicle to the steering wheel is determined continuously; a lane-holding steering torque which is required for guiding the vehicle in the prevailing lane is regulated; at least one upper limit value (limit torque  $M_{H,HIGH}$ ) for the additional assistance torque applied to the steering wheel is preselected, and the lane-holding steering torque is reduced according to a preselected function, preferably a time-controlled ramp function, preferably reducing it to a value of

ZERO. A linearly declining function with a slope in the range of 2.5 Nm to 3.0 Nm is preferably preselected as the time-controlled ramp function.

This object is also achieved by a steering torque regulating module which is provided in particular for performing the inventive method and is characterized in that an additional assistance torque  $M_{ASS}$  is applied to a manual steering wheel of the vehicle, by means of which the driver of the vehicle is assisted in driving in a lane.

This object is likewise achieved by a vehicle having a vehicle steering system and having a lane guidance system which includes a steering torque regulating module according to this invention.

This invention is explained in greater detail below as an example on the basis of three illustrations (Figure 1 through Figure 3).

Figure 1 shows a diagram of a torque limitation of the additional assistance torque according to this invention, which depends on the manual torque.

Figure 2 shows an "external" limitation on the additional assistance torque with a time-controlled opening.

Figure 3 shows an "external" limitation on the additional assistance torque with a lane change-controlled opening.

A vehicle is equipped with a driver assistance system for "automatic" lane guidance (lane guidance system) according to this invention. The lane guidance system has a system component

for detecting the driver's intent, recognizing the driver's intent when the "automatic" lane guidance is active and controlling the lane guidance system according to this intent so that his intent is manifested in a comfortable fashion.

In "automatic" lane guidance, the driver assistance system delivers a steering recommendation which is more or less impressed upon the driver via a steering angle setpoint value and/or a steering torque setpoint value (assistance torque) to a steering regulating system, depending on the system parameterization. In addition to the steering movements calculated by the assistance system, there are also steering movements due to feedback from interference due to the road and due to the driver himself. First, the system must compensate for this interference but, secondly, it must not force the driver into a certain direction of driving against his wishes, because the driver may need to respond to an imminent threat or may want to perform a lane change.

To fulfill this purpose according to this invention, the torque applied by the driver to the steering wheel (manual torque) is detected by a torque sensor. If the driver follows the steering recommendation of the assistance system, the manual torque is approximately zero or at least very low. If the driver deviates from the automatic lane guidance recommendation, it results in a significant increase in the manual torque because in this case the driver is operating against the assistance system. A basic goal of the present invention is to detect and interpret the driver's intent based on the variations in manual torque and to achieve a comfortable transition between the driver and system by dynamically adapting the maximum preselectable assistance torque  $M_{ASS}$  to the manual torque  $M_H$  applied by the driver.

This procedure is explained in greater detail below with reference to Figure 1. Figure 1 shows a curve for the manual torque  $M_H$  plotted as a function of the assistance torque  $M_{ASS}$  with an upper limit torque  $M_{H,HIGH}$  and a lower limit torque  $M_{H,LOW}$ .

If the torque remains below a first threshold value (lower limit torque  $M_{H,LOW}$ ) during a trip with the automatic lane guidance activated, then it is perceived as interference and is compensated by the regulator of the lane guidance system (left horizontal line I in Figure 1). In doing so, the assistance torque  $M_{ASS}$  is raised to an upper limit value  $M_{ASS,max}$ . In the regulation, at least the upper limit value  $M_{ASS,max}$  of the assistance torque  $M_{ASS}$  is dynamically adaptable to the manual torque  $M_H$  currently being applied by the driver of the vehicle to the steering wheel. This is represented by the dotted lines IV, V and VI in Figure 1.

It is advantageous here that the signal of the manual torque is processed through suitable filters so that short-term peaks in the signal characteristic do not generate an output signal above  $M_{H,LOW}$ , in particular when such peaks occur due to the inertia of the steering column and the steering wheel in combination with interference from the road (such as potholes).

If in the remaining course the manual torque thus determined increases further due to compensation by the regulator of the lane guidance system, then there is in all probability a driver's intent to drive in another direction of travel than that calculated by the lane guidance system. To be able to conform to this intent, first the compensation effect is limited by the lane guidance system which is still active in such a



manner that the torque required for guiding the vehicle in the lane is limited to a maximum value in a linear relationship with an increase in manual torque (falling line II in Figure 1).

If the manual torque value reaches an upper threshold (upper limit torque  $M_{H,HIGH}$ ), then in all probability there is a driver's intent for a different direction of travel that deviates significantly from the direction of travel calculated by the lane guidance system. Assistance torque  $M_{ASS}$  is then limited to a lower limit value  $M_{ASS,min}$  (right horizontal line III in Figure 1).

On reaching this upper threshold value  $M_{H,HIGH}$ , there is an "external" compensation limitation. This is depicted in Figure 2 and in Figure 3 in the plot of the curve of the assistance torque  $M_{ASS}$  as a function of time  $t$ .

In "external" compensation limitation, the torque required for guiding the vehicle in the lane is additionally regulated by a time-controlled ramp. The torque is regulated at the value 0 (ZERO) starting from the compensation value determined and already limited at the point in time of reaching the upper threshold value. This is advantageously done in such a way that the output value  $M_{ASS,max}$  (left line VII in Figures 2 and 3) for the linear limitation described above is regulated at ZERO (falling line VII in Figures 2 and 3). For the driver of the vehicle, this situation again results in a "normal" steering feeling so that the driver can execute lane change maneuvers or yielding maneuvers, as is known by driving without automatic lane guidance. The takeover of the vehicle by the driver is implemented.

If in the remaining course of the trip, the manual torque is below the lower threshold value  $M_{H,LOW}$  for a period of time  $t_1 > T1$  (see Figure 2, center) or if the lane guidance system has detected a lane change and the manual torque has already been below the lower threshold value  $M_{H,LOW}$  for a period of time  $t_2 > T2$  (see Figure 3, center), then it is assumed that the driver of the vehicle has agreed to allow the lane guidance system to take over lane guidance again.

If it has been detected that the driver of the vehicle has agreed to allow the lane guidance system to take over the lane guidance again, then the "external" compensation limitation is opened. This means that the initial value for the linear limitation which depends on the manual torque is controlled at a maximum value (horizontal line X in Figures 2 and 3) via a time-controlled ramp (line IX increasing over time in Figure 2 and 3). First, guidance parameters for a regulator of the lane guidance system are determined, whereupon the steering angle calculated initially corresponds to the steering angle currently being set by the driver of the vehicle. During the time of takeover by the system, these guidance parameters are controlled at a value of 0 (ZERO) via time ramps. If these guidance parameters have become 0 (ZERO) then the system takeover has been accomplished.

The method can be implemented in part or combined with known methods. In addition to the methods described here, these also include possible visual or acoustic instructions or other haptic feedback (e.g., via the accelerator pedal) for the driver of the vehicle for the purpose of remaining in one lane.